Physical Therapy in Sport 42 (2020) 26–32

Contents lists available at ScienceDirect

Physical Therapy in Sport

journal homepage: www.elsevier.com/ptsp

Original Research

Four-year match injury surveillance in male Welsh professional Rugby Union teams

Charlotte Leah Bitchell [a, *], Prabhat Mathema [b], Isabel S Moore [a]

[a] Cardiff Metropolitan University, Cyncoed Campus, Cyncoed Road, Cardiff, Wales, CF23 6XD, United Kingdom
[b] Welsh Rugby Union, National Centre of Excellence, Vale Hotel, Hensol, Wales, CF72 8JY, United Kingdom

ARTICLE INFO

Article history:
Received 5 June 2019
Received in revised form
26 November 2019
Accepted 3 December 2019

Keywords:
Rugby Union
Injury
Incidence
Burden

ABSTRACT

Objectives: To report match injury incidence, burden and mechanism over a four-year period in professional male Welsh Regional Rugby Union. ***Design:*** Descriptive; Longitudinal. ***Setting:*** Welsh Regional Rugby Union. ***Participants:*** Four Welsh Regional male Rugby Union teams. ***Main Outcome Measures:*** All time-loss injuries sustained between July 1, 2012 and June 30, 2016. Incidence (injuries/1000 h), severity (mean and median days lost per injury), burden (days-lost/1000 h) and proportions (%) were calculated. ***Results:*** The overall injury incidence and burden was 99.1 injuries/1000 h and 2570.3 days-lost/1000 h. Concussion represented the highest incidence and burden of all specific injuries, with increases in burden from 2012/13 (86.5 days-lost/1000 h) to 2015/16 (302.4 days-lost/1000 h). Acromio-clavicular (AC) joint injuries increased in burden from 2012/13 to 2015/16 (71.3 vs 130.6 days-lost/1000 h). However, anterior thigh haematomas decreased in incidence (8.2 vs 2.4 injuries/1000 h) and burden (48.6 vs 17.7 days lost/1000 h) across the same period. Tackle events contributed to the highest proportion of match injuries (being tackled: 20–31%, tackling: 30–42%). ***Conclusions:*** Injury incidence was higher than previously reported for professional Rugby Union. Decreases in anterior thigh haematoma and increases in concussion and AC joint injuries were shown, identifying a change in contact-related match injury risk.

1. Introduction

Understanding injury risk and establishing effective injury prevention relies on a well-structured and proficient data collection. The Translating Research into Injury Prevention Practice (TRIPP) framework was established to guide injury research, with surveillance constituting the first stage of data collection (Finch, 2006). A number of different sports have published injury surveillance research, however, inconsistency in definitions and data collection procedures make comparisons between sports challenging. Consequently, the consensus statement on injury definitions and data collection procedures was developed in Rugby Union to allow consistent data collection and comparisons to be made between studies (Fuller et al., 2007a). Injury surveillance research in Rugby Union has been published in many different countries including England, Wales, Australia and South Africa (Bathgate et al., 2002; Brooks et al., 2005; Holtzhausen et al., 2006; Moore, Ranson, & Mathema, 2015; Rafferty et al., 2018; Williams et al., 2017), and incidence rates have remained consistently high within Rugby Union when compared to other team sports (Williams et al., 2013). Across different levels of Rugby Union, injury incidence has ranged from 55.4 injuries per 1000 match hours at a professional club level to 180 per 1000 match hours for a single international team (Fuller, Sheerin, & Targett, 2013; Holtzhausen et al., 2006; Moore et al., 2015). However, professional club level studies have primarily focused on clubs from a single country and matches between clubs in the same country or within the same hemisphere. Injury burden is also high in Rugby Union, where injury burden within multiple professional Rugby Union teams across one season has shown values as high as 1795 days-lost per 1000 h (Rugby Football Union (Eng, 2016). The high incidence and burden is further emphasised when compared with other team sports, where incidence and burden is lower, with incidence ranging from 7.1 to 77.3 injuries per 1000 match-hours in cricket and football, respectively, and a burden of 88.5 days-lost per 1000 h

* Corresponding author. Cardiff School of Sport and Health Sciences, Cyncoed Campus, Cardiff, CF23 6XD, United Kingdom
E-mail addresses: st20019889@outlook.cardiffmet.ac.uk (C.L. Bitchell), pmathema@wru.wales (P. Mathema), imoore@cardiffmet.ac.uk (I.S. Moore).

https://doi.org/10.1016/j.ptsp.2019.12.001
1466-853X/

reported in football (Ekstrand, Waldén, & Hägglund, 2016; Junge & Dvorak, 2013; Ranson et al., 2013).

The differences in incidence between Rugby Union and other team sports are primarily due to the demands placed upon players during matches, with Rugby Union requiring many different high intensity and collision based movement patterns (Owen et al., 2015; Roberts et al., 2008). Within Rugby Union matches, two teams compete against each other, with each team on the field of play consisting of 15 players split into eight forwards and seven backs. The physical demand often differs between positions, with forwards often spending more time competing for the ball than the backs, resulting in a greater number of impact events (Owen et al., 2015). The differing positional demands often result in different injury risk, with forwards sustaining a higher number of injuries than the backs, but the backs sustaining more severe injuries (Bathgate et al., 2002; Brooks et al., 2005; Owen et al., 2015). However, even with differences in match demands the injuries across body areas remains similar (Owen et al., 2015). When specific body areas are considered in overall injury analysis, previous research has revealed that the head and shoulder were the most common match injuries (Bathgate et al., 2002; Best, McIntosh, & Savage, 2005; Fuller et al., 2013; Moore et al., 2015), with the knee often constituting the most severe injury, resulting in the highest number of days absence (Bathgate et al., 2002; Brooks et al., 2005; Fuller et al., 2008, 2013). Moreover, when regarding specific injuries, concussion has been one of the most problematic and consistent injuries occurring in Rugby Union, with the incidence rising year-on-year since 2006, ranging from 1.4 per 1000 h at a professional club level (Holtzhausen et al., 2006) to 21.5 per 1000 h in the professional and international level combined (Rafferty et al., 2018). With consistently high overall injury incidence as well as rising incidence of specific injuries, understanding the causes of injuries is essential. Previous research has consistently identified that contact events during matches constitutes the principle cause of injuries, where tackling or being tackled currently accounts for 40–58% of match injuries (Bathgate et al., 2002; Best et al., 2005; Fuller et al., 2007b, 2008, 2013; Holtzhausen et al., 2006; Moore et al., 2015).

The current understanding regarding professional club Rugby Union injury rates are based on single country or single hemisphere matches (Brooks et al., 2005; Holtzhausen et al., 2006). Yet different styles of play have been reported across hemispheres (Pulling & Stenning, 2015), which may influence injury rates. Clubs within Wales play matches against clubs from different countries and against clubs in the Southern Hemisphere. However, it is unknown whether injury incidence of the professional clubs in Wales is similar to previously reported rates, in addition to whether injury rates and mechanisms have changed over recent seasons. Therefore, the aim of this study was to assess match injury incidence, burden and mechanism over a four-year period for the four professional male Welsh Regional Rugby Union teams. Additionally, match injury incidence and burden for forwards and backs was compared over the four-year period.

2. Methods

2.1. Participants

The Welsh Rugby Union injury surveillance programme was established in 2012 and player injury records from the four professional male Welsh Regional Rugby Union teams, the only professional level Rugby Union clubs in Wales, have been collected since its inception. The prospective nature of the data collection removes potential recall errors that can occur with retrospective reporting of player exposure and injury occurrence (Fuller et al., 2007a). Participants were the players selected for the first team squad of each club across the four seasons, with each player providing informed consent for their injury data to be collected and analysed. To be considered a first team player, participants must predominantly have been selected for the first team rather than an Academy or second team. Ethical approval was obtained from the University's Research Ethics committee.

2.2. Procedure

The surveillance period reported covers four seasons (2012/13, 2013/14, 2014/15 and 2015/16), from July 1, 2012 to June 30, 2016. The injury definitions and data collection procedures followed the recommendations from the international consensus statement on Rugby Union injury surveillance (Fuller et al., 2007a).

Baseline information about player position, date of birth and anthropometrics for each player that participated in regional competitions was provided. Throughout the four seasons, one designated medical team member from each regional team recorded all time-loss injuries. At the end of each month all data was sent to an independent researcher at the University (ISM). Injury records and exposure data were checked and reconfirmed if necessary to minimise missing data. The designated medical team member was responsible for recording injury details such as: date of injury and return to play, injury location, Orchard Sports Injury Classification System (OSICS) code (Rae & Orchard, 2007), playing position (forward or back), mode of onset (gradual, sudden, impact, insidious), mechanism of injury (contact or non-contact) and injury recurrence. Only injuries sustained when training or playing for regional competitions i.e. the Celtic League/PRO 14, European competitions, Anglo Welsh cup and any practice matches, were used during analysis. Based on the injury diagnosis from the OSICS code, the incidence and burden for the top five specific injuries was calculated for each season.

2.3. Definitions

All definitions for injury were based on the international Consensus Statement for Rugby Union (Fuller et al., 2007a). The primary injury definition used for the study was:

> *"Any physical complaint sustained by a player during the season that rendered the player unavailable for match selection for more than one day, following midnight of the day of injury, irrespective of whether a match was actually scheduled on that day".* (Fuller et al., 2007a)

The recurrence of an injury was reported based on the clinical judgement of the designated medical team member collecting the injury data. The recurrent injury definition used for this study was:

> *"An injury of the same type and at the same site as an index injury and which occurs after a player's return to full participation from the index injury".* (Fuller et al., 2007a)

2.4. Data analysis

Match exposure was calculated based on 15 players being exposed for 80 min and where forward and backs were compared, exposure was based on either eight or seven players playing for 80 min respectively. Match injury incidence was calculated as the number of injuries per 1000 match hours, with 95% confidence intervals (CI) calculated using the Poisson distribution (John, 2013).

The severity of injuries were presented as both the mean days unavailable (SD) and median days unavailable, with interquartile range (IQR). Injury burden was calculated as days-lost per 1000 h ((∑ days-lost/∑ exposure hours)x1000) and provides an overview of injury risk (Ekstrand et al., 2013; Fuller, 2018), with 95% confidence intervals (CI) calculated using the Poisson distribution (John, 2013). All data was tested for normal distribution. Match incidence and severity for forwards and backs were analysed separately. Forwards and backs data were combined to analyse injuries based on body area, mechanism of injury and recurrent nature of injuries. To compare two injury incidences a rate ratio (RR) was calculated, with a significant difference identified by the 95% CI for the RR not intersecting with unity. Comparisons for significant differences between positional height and weight, number of injuries per season and mean injury severity per season was analysed using the Mann-Whitney-Wilcoxon test. Comparisons for significant differences between the number and mean severity of injuries across seasons within positions was analysed using the Friedman test. Comparisons for significant differences between seasons for body area was analysed using the Kruskal-Wallis test. Significance was accepted as $p < 0.05$ and all significance testing were computed in R (Core Team. R, 2013).

3. Results

A total of 783 players were selected across the four seasons, with squad sizes remaining similar between each season, ranging from 40 to 57 players (49 ± 5.1). Forwards were significantly taller (189.4 ± 6.9 cm vs 183.9 ± 5.9 cm, respectively, $p < 0.001$) and heavier than the backs (110.8 ± 8.7 kg vs 92.5 ± 8.0 kg, respectively, $p < 0.001$). The proportion of matches played against non-Welsh professional clubs was 79%, with only 21% of matches played against professional clubs within Wales. Sixty-one percent of players sustained at least one match time-loss injury in 2012/13, 56% in 2013/14, 59% in 2014/15 and 51% in 2015/16. A total of 548 matches were played throughout the four seasons (range: 124 to 143 matches per season), equating to 10960 match hours overall. There were 1086 match injuries across the four seasons, equating to an injury incidence of 99.1 injuries per 1000 match hours. There was a total of 28,170 days unavailable due to injury across the four seasons, equating to an overall burden of 2570.3 days-lost per 1000 match hours.

3.1. Position (forwards vs backs)

The overall number of match injuries and match injury incidence was similar between positions (forwards: 621 injuries, 106.4 injuries/1000 h; backs: 443 injuries, 86.8 injuries/1000 h; RR: 1.23, 95% CI 0.92–1.63). Even though the forwards appeared to have a higher injury incidence (range: 92.4–117.4 injuries/1000 h) than the backs (range: 74.0–86.4 injuries/1000 h) there was no significant difference in the number or incidence of match injuries between positions across the four seasons (Fig. 1).

There was a similar number of mean days-lost per injury (injury severity) across the four seasons (Supplementary Figure A). The overall burden across the four seasons was similar between positions (2548.7 vs 2542.2 days-lost/1000 h for forwards and backs, respectively). Injury burden was higher for the backs than the forwards in the 2013-14 and 2015-16 season, with forwards showing a peak above the backs injury burden only in the 2014-15 season (Fig. 2).

3.2. Body region

The head, shoulder, knee and ankle had the highest match injury incidence across the four seasons (Table 1), with only the head injury incidence showing a significant increase from 2012/13 to 2015/16. Of the head injuries, 80–95% each year were concussions. Match injury burden for the shoulder and knee were consistently higher than any other body region (Table 1). The mean severity was similar between seasons for all body areas (Supplementary Table A).

Where specific injuries are concerned, concussion incidence increased and anterior thigh haematoma incidence decreased from the 2012/13 to the 2015/16 season (Table 2). However, no other significant changes in specific injuries were observed. The severity of the three specific injuries that were in the top five injury incidence for at least three seasons remained similar across the four seasons. Concussion injury incidence and burden was the highest of all specific injuries, with an increase in burden shown from the 2012/13 to the 2015/16 season (86.5 vs 302.4 days-lost per 1000 h, respectively). An increase in burden was also seen for the acromioclavicular (AC) joint (71.3 in 2012/13 vs 130.6 days-lost per 1000 h in 2015/16), whereas anterior thigh haematoma was the only injury to show a decrease in injury burden (48.6 in 2012/13 vs 17.7 days lost per 1000 h in 2015/16).

3.3. Mode and mechanism of injury

The incidence and burden of each mode of onset for match injuries is shown in Table 3. Impact and sudden onset were responsible for the highest percentage of injuries (38–55%) across each season. For the mechanism of injuries, between 72 and 80% of match injuries were due to contact mechanisms, with similar values shown across the four seasons. The three main mechanisms of contact injuries were collision, tackled and tackling (12–21%, 20–31% and 30–42% respectively) where seasonal values were similar.

3.4. Injury recurrence

The percentage of recurrent injuries remained similar across the four seasons (mean 17% ± 1.9). The overall incidence of recurrent injuries was 17.2 injuries per 1000 h, with values remaining similar each year (incidence range: 15.0–21.7). The overall severity of recurrent injuries across the four seasons was 28 ± 2.5 days-lost, with severity remaining similar between recurrent and non-recurrent injuries throughout each season (recurrent range: 25–30; non-recurrent range: 22–29 days unavailable; $p = 0.19$).

4. Discussion

The aim of this study was to investigate injury rates across four seasons in professional Welsh Regional professional Rugby Union teams and compare positional differences in match injury incidence, severity and burden. The number, incidence and severity of match injuries were similar between forwards and backs. The head, shoulder and knee body regions had the highest injury incidence for both positions, and the shoulder and knee had the highest injury burden. When considering more specific injuries, concussion accounted for the highest injury incidence for both positions and increased over the surveillance period, but there was a reduction in the incidence of anterior thigh haematomas for the same period.

4.1. Injury incidence

Overall match injury incidence in the current study was 99.1 injuries per 1000 match hours, which is higher than that previously reported in professional club Rugby Union (55.4, to 91 injuries per1000 h) (Brooks et al., 2005; Holtzhausen et al., 2006; Ranson et al.), but lower than that reported for international level Rugby

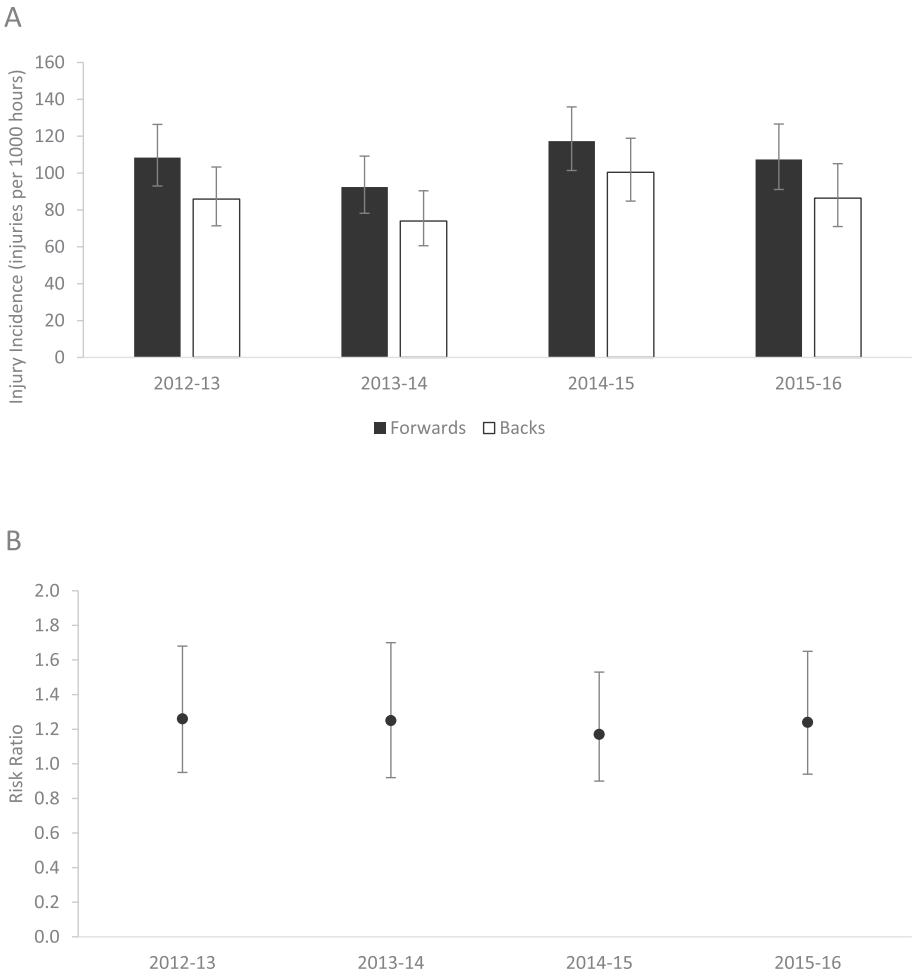

Fig. 1. A) Match injury incidence (injuries per 1000 h) for forwards and backs for each regional season. Bars represent upper and lower CI. B) The RR between the injury incidence of forwards and backs for each regional season. Bars represent upper and lower CI.

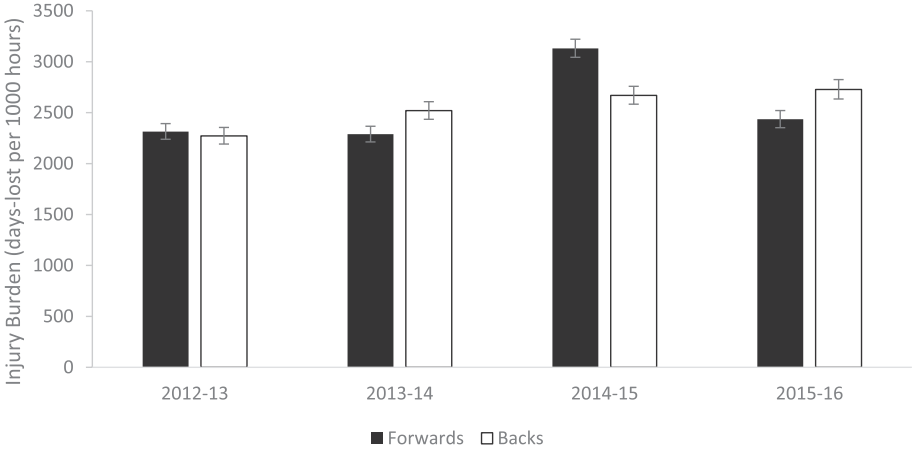

Fig. 2. Match injury burden (days-lost per 1000 h) for forwards and backs for each regional season. Bars represent upper and lower CI.

Union (180 injuries per 1000 h) (Moore et al., 2015). The differences shown between professional club level injury incidence rates could be attributed to the increased exposure to multi-continent competitions in the current research. Specifically, 79% of matches were against clubs outside of Wales, whilst previous research has either involved only one hemisphere or not reported the proportion of different countries or hemispheres involved. (Brooks et al., 2005; Holtzhausen et al., 2006). Differences between injury incidence in the professional and international level can be attributed to the differences in both the intensity and number of matches, with a lower number of matches played within a season and increased demands placed upon players at the international level (Moore et al., 2015; Williams et al., 2013).

Table 1
Match injury incidence (injuries per 1000 h) and injury burden (days-lost per 1000 h) with upper and lower CI.

Body Area	Season			
	2012–13	2013–14	2014–15	2015–16
Head				
Incidence	12.4 (8.9–17.3)	13.2 (9.6–18.2)	20.3 (15.7–26.3)	22.6 (17.4–29.4)
Burden	115.2 (103.3–128.4)	155.4 (141.4–170.7)	316.4 (296.4–337.7)	309.3 (288.2–332.0)
Neck				
Incidence	6.0 (3.7–9.7)	3.9 (2.2–7.0)	5.2 (3.1–8.6)	5.6 (3.3–9.5)
Burden	192.2 (176.7–209.1)	28.2 (22.6–35.2)	57.7 (49.5–67.2)	112.9 (100.4–126.9)
Shoulder				
Incidence	12.4 (8.9–17.3)	11.8 (8.4–16.6)	11.9 (8.5–16.7)	11.7 (8.1–16.8)
Burden	437.9 (414.1–463.0)	476.8 (451.9–503.1)	668.2 (638.9–698.8)	401.2 (377.0–426.9)
Elbow				
Incidence	1.1 (0.4–3.4)	2.1 (0.9–4.7)	0.4 (0.1–2.8)	0.4 (0.1–2.8)
Burden	87.6 (77.3–99.2)	34.3 (28.1–41.9)	42.0 (35.1–50.2)	26.2 (20.5–33.4)
Forearm				
Incidence	0.7 (0.2–2.8)	0.7 (0.2–2.8)	0.3 (0.04–2.1)	0.4 (0.1–2.8)
Burden	20.2 (15.6–26.2)	98.9 (87.9–111.3)	97.9 (87.1–110.1)	5.2 (3.0–9.0)
Wrist & Hand				
Incidence	4.6 (2.7–7.9)	3.6 (1.9–6.7)	4.9 (2.9–8.3)	1.6 (0.6–4.3)
Burden	76.6 (67.0–87.5)	103.6 (92.3–116.2)	263.3 (245.1–282.8)	95.6 (84.2–108.6)
Chest				
Incidence	3.2 (1.7–6.2)	1.4 (0.5–3.7)	2.4 (1.1–5.0)	2.4 (1.1–5.3)
Burden	47.5 (40.1–56.3)	58.6 (50.3–68.3)	21.7 (16.9–27.8)	26.6 (20.9–33.9)
Lumbar				
Incidence	2.8 (1.4–5.6)	1.8 (0.7–4.3)	1.4 (0.5–3.7)	0.8 (0.2–3.2)
Burden	13.5 (9.8–18.6)	11.4 (8.1–16.1)	9.8 (6.8–14.2)	6.9 (4.3–11.1)
Hip/Groin				
Incidence	7.1 (4.6–11.0)	3.6 (1.9–6.7)	6.6 (4.2–10.4)	3.2 (1.6–6.4)
Burden	85.1 (75.0–96.6)	31.8 (25.8–39.1)	99.7 (88.8–112.0)	25.0 (19.5–32.1)
Posterior Thigh				
Incidence	6.7 (4.3–10.5)	6.1 (3.8–9.8)	6.6 (4.2–10.4)	7.7 (4.9–12.1)
Burden	155.7 (141.8–171.0)	162.5 (148.2–178.1)	115.7 (103.9–128.9)	172.6 (157.0–189.8)
Anterior Thigh				
Incidence	7.8 (5.1–11.9)	5.4 (3.3–9.0)	12.2 (8.8–17.0)	7.3 (4.6–11.6)
Burden	47.5 (40.1–56.3)	41.1 (34.2–49.3)	110.5 (99.0–123.4)	58.1 (49.3–68.4)
Knee				
Incidence	11.7 (8.3–16.5)	10.4 (7.2–15.0)	13.6 (9.9–18.6)	11.7 (8.1–16.8)
Burden	451.8 (427.7–477.3)	548.6 (521.8–576.7)	511.5 (485.9–538.4)	695.2 (663.1–728.8)
Lower Leg				
Incidence	7.4 (4.8–11.4)	5.7 (3.5–9.3)	5.2 (3.1–8.6)	7.3 (4.6–11.6)
Burden	206.7 (190.6–224.2)	86.8 (76.5–98.4)	51.0 (43.4–60.0)	73.0 (63.1–84.5)
Ankle				
Incidence	9.2 (6.3–13.5)	8.9 (6.0–13.2)	12.9 (9.3–17.8)	6.9 (4.3–11.1)
Burden	230.5 (213.4–248.9)	337.9 (317.0–360.1)	377.3 (355.4–400.5)	241.1 (222.5–261.2)
Foot				
Incidence	2.1 (0.9–4.7)	2.9 (1.5–5.8)	2.4 (1.1–5.0)	4.0 (2.2–7.4)
Burden	111.3 (99.6–124.3)	183.6 (168.4–200.2)	54.5 (46.6–63.8)	161.3 (146.2–177.9)

Table 2
Match injury incidence (injuries per 1000 h) and injury burden (days-lost per 1000 h), with upper and lower CI, mean injury severity, with standard deviation and median severity with the interquartile range, of the three specific injuries that were in the top five injury incidence for at least three seasons.

Injury	Season			
	2012–13	2013–14	2014–15	2015–16
Concussion				
Incidence	10.6 (7.4–15.2)	11.4 (8.1–16.1)	17.8 (13.5–23.4)	21.4 (16.3–28.0)
Burden	86.5 (76.3–98.1)	112.9 (101.1–126.1)	266.1 (247.8–285.7)	302.4 (281.5–324.8)
Mean Severity	8.1 (5.8)	9.9 (3.9)	14.7 (23.1)	14.1 (21.3)
Median Severity	6 (5.3–10.0)	9 (8.0–10.3)	8 (6.0–12.5)	10 (7.0–14.8)
Anterior Thigh Haematoma				
Incidence	8.2 (5.4–12.3)	6.1 (3.8–9.8)	7.7 (5.1–11.7)	2.4 (1.1–5.3)
Burden	48.6 (41.1–57.5)	32.5 (26.5–39.9)	60.5 (52.1–70.2)	17.7 (13.2–23.8)
Mean Severity	6 (3.2)	5 (3.5)	8 (7.9)	7 (4.5)
Median Severity	5 (3.5–9.0)	4 (3.0–5.0)	5 (3.0–8.0)	5 (4.3–11.0)
Acromio-Clavicular (AC) Joint				
Incidence	3.9 (2.2–7.0)	3.9 (2.2–7.0)	5.2 (3.1–8.6)	5.6 (3.3–9.5)
Burden	71.3 (62.1–81.9)	73.2 (63.8–83.9)	97.6 (86.8–109.8)	130.6 (117.1–145.6)
Mean Severity	18 (27.5)	17 (9.8)	19 (18.2)	23 (31.7)
Median Severity	7 (4.5–21.0)	17 (11.0–22.3)	13 (10.0–17.0)	15 (9.3–20.3)

Table 3
The incidence (injuries per 1000 h) and burden (days-lost per 1000 h) with upper and lower CI, of each injury mode of onset from the 2012-13 to the 2015-16 season.

Mode of Onset	Season			
	2012–13	2013–14	2014–15	2015–16
Impact				
Incidence	46.5 (39.2–55.2)	37.9 (31.3–45.9)	53.8 (45.9–63.0)	38.3 (31.3–46.8)
Burden	964.2 (928.6–1001.1)	645.7 (616.6–676.2)	1329.0 (1287.4–1371.9)	645.6 (614.7–678.0)
Sudden Onset				
Incidence	40.1 (33.3–48.2)	42.1 (35.1–50.4)	45.8 (38.6–54.4)	43.5 (36.0–52.5)
Burden	1125.9 (1087.4–1165.8)	1708.9 (1661.2–1758.0)	1405.2 (1362.4–1449.3)	1639.1 (1589.5–1690.3)
Gradual Onset				
Incidence	9.6 (6.6–14.0)	3.2 (1.7–6.2)	7.3 (4.8–11.2)	8.1 (5.2–12.6)
Burden	237.6 (220.3–256.3)	24.6 (19.4–31.2)	67.8 (58.9–78.0)	160.5 (145.5–177.1)
Insidious				
Incidence	3.2 (1.7–6.2)	0.7 (0.2–2.8)	4.9 (2.9–8.3)	8.9 (5.9–13.5)
Burden	16.7 (12.5–22.2)	7.1 (4.6–11.0)	136.7 (123.8–150.9)	153.2 (138.5–169.4)

4.2. Injuries and injury risk

The head, knee and shoulder were the body regions with the highest injury incidence and burden, following a similar trend seen in previous injury surveillance research (Bathgate et al., 2002; Moore et al., 2015; Fuller et al., 2008, 2013). When separated into specific injuries, the injury burden of concussion was 50–60% higher than any other specific injury (Table 2) and also had the highest combined injury incidence across four seasons (15.3 injuries per1000 match hours). The increase in head injury incidence over time, and high incidence and burden of concussion, supports similar finding in previous research (e.g. 6.6 concussions per1000 player hours in 2008 (Brooks & Kemp, 2008) to 15.8 concussions per1000 h in 2016 (Rugby Football Union (Eng, 2016)) and emphasises that concussion continues to be a priority injury throughout Rugby Union (Moore et al., 2015; Rugby Football Union (Eng, 2016; Brooks & Kemp, 2008). Although concussion remains a priority for injury prevention, the increases seen from research published in 2008 can also be attributed to increasing awareness through compulsory education on concussion symptoms and diagnosis, alongside the introduction of World Rugby's, the global governing body, Head Injury Assessment protocol in the professional game (Cross et al., 2017; World Rugby, 2019). Within Wales, concussion education was mandated for all key stakeholders involved in Rugby Union (players, clinicians, referees and coaches) and directly targeted concussion knowledge deficits and common misconceptions identified by Mathema et al. (Mathema et al., 2016)

Interestingly, AC joint injury burden was the only other specific injury to show an increase from the 2012/13 to the 2015/16 season. Additionally, anterior thigh haematomas were the only injury to show a decrease in injury incidence and burden (48.6 vs 17.7 days-lost per 1000 h in 2012/13 and 2015/16, respectively). These findings, together with the increase in concussion incidence and unchanged match injury incidence, show that the injury risk is changing within Rugby Union. Over the surveillance period, the following trend was observed, a larger injury risk to the upper body region accompanied by a lower impact-related injury risk to the lower body region. It is conceivable that this change in injury risk is associated with the tackle event, which caused between 50 and 63% of all match injuries across the four seasons. Contact, and specifically, the tackle event has consistently been reported as causing the highest proportion of match injuries (Bathgate et al., 2002; Best et al., 2005; Fuller et al., 2007b, 2008, 2013; Holtzhausen et al., 2006; Moore et al., 2015). Tackle technique may therefore be changing towards connecting with a ball carrier higher up the body, and whilst high tackle technique has been identified as a risk factor (Brooks & Kemp, 2008; Fuller et al., 2007b), it is not known whether tackle technique has been changing over previous years. However, new tackle sanction categories have been introduced by World Rugby to mitigate this injury risk (Tucker et al., 2017), where preliminary data showed the incidence of tackle-related injuries and concussions was similar before and after the new sanctions (Rugby Football Union (Eng, 2016). It remains to be seen whether continued use of the tougher sanction helps reduce injury risk across Rugby Union.

In contrast to previous findings, recurrent injuries had a similar severity to new injuries (Brooks et al., 2005; Ekstrand, Hägglund, & Waldén, 2011; Walden, Hagglund, & Ekstrand, 2005), however incidence remained substantially lower each season. The differences observed in the current study in comparison to previous research could be due the recurrent injury diagnosis being based solely on the recall of the clinician. In an attempt to remove clinician recall bias, the subsequent injury categorisation (SIC 2.0) was developed to provide a more accurate categorisation of subsequent injuries (Toohey et al., 2018). Future research should therefore review the use of clinical recall to diagnose recurrent injuries and utilise the SIC 2.0 to provide more accurate diagnosis of subsequent injuries.

4.3. Limitations

One of the main limitations in the current study was the potential difference in injury reporting due to changes in medical personnel throughout the four seasons. Previous injury surveillance has identified that changes in reporting behaviour can impact upon the injury rates (Moore et al., 2015). However, a standardised approach was implemented across all four teams and data were checked monthly by an independent researcher during the data collection period, meaning any anomalies in reported data were amended accordingly.

5. Conclusion

Injury incidence was higher than previously reported for professional club Rugby Union, with the incidence and burden remaining similar between the positional groups. The higher incidence rate identified by the current study warrants further exploration to establish whether there is a general trend towards increasing injury rates over recent years. A changing match injury risk was observed, with reductions in anterior thigh haematomas but increases in concussion and AC joint incidence and burden leading to the overall match injury incidence remaining relatively stable. Tackle technique could be a risk factor contributing to these changes observed over the seasons. Further work considering the mechanism behind these changes is warranted, specifically examining tackle techniques over the previous four seasons.

Acknowledgements

The authors would like to thank the physiotherapists and strength and conditioning coaches at the four regional WRU clubs who diligently recorded all injury and exposure data throughout the project.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2019.12.001.

Conflict of interest

ISM received a research grant from Welsh Rugby Union. PM is head of Medical Services at Welsh Rugby Union.

Funding

The lead author (CLB) was funded by the Knowledge Economy Skills Scholarships (KESS 2). The KESS 2 is a pan-Wales higher level skills initiative led by Bangor University on behalf of the HE sector in Wales. It is part funded by the Welsh Government's European Social Fund (ESF) convergence programme for West Wales and the Valleys.

Ethical statement

Ethical approval was obtained from Cardiff Metropolitan University Ethics Committee (project reference number: 18-7-02S). All participants provided voluntary written informed consent before participating.

Contributors

ISM, PM and CLB conceived and designed the study. CLB analysed and interpreted the data and prepared the initial draft of the manuscript. ISM and PM made substantial critical contributions to the revisions of the manuscript prior to submission.

References

Bathgate, A., Best, J. P., Craig, G., et al. (2002). A prospective study of injuries to elite Australian rugby union players. *British Journal of Sports Medicine, 36*, 265–269. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=2003015212&site=ehost-live.

Best, J. P., McIntosh, A., & Savage, T. N. (2005). Rugby World Cup 2003 injury surveillance project. *British Journal of Sports Medicine, 39*, 812–817. https://doi.org/10.1136/bjsm.2004.016402.

Brooks, J. H. M., Fuller, C. W., Kemp, S. P. T., et al. (2005). Epidemiology of injuries in English professional rugby union: Part 1 match injuries. *British Journal of Sports Medicine, 39*, 757–766. https://doi.org/10.1136/bjsm.2005.018135.

Brooks, J. H. M., & Kemp, S. P. T. (2008). Recent trends in rugby union injuries. *Clinics in Sports Medicine, 27*, 51–73. https://doi.org/10.1016/j.csm.2007.09.001.

Cross, M. J., Tucker, R., Raftery, M., et al. (2017). *Tackling concussion in professional rugby union : A case – control study of tackle-based risk factors and recommendations for primary prevention* (pp. 1–6). https://doi.org/10.1136/bjsports-2017-097912.

Ekstrand, J., Hägglund, M., Kristenson, K., et al. (2013). Fewer ligament injuries but no preventive effect on muscle injuries and severe injuries: An 11-year follow-up of the UEFA Champions League injury study. *British Journal of Sports Medicine, 47*, 732–737. https://doi.org/10.1136/bjsports-2013-092394.

Ekstrand, J., Hägglund, M., & Waldén, M. (2011). Epidemiology of muscle injuries in professional football (soccer). *The American Journal of Sports Medicine, 39*, 1226–1232. https://doi.org/10.1177/0363546510395879.

Ekstrand, J., Waldén, M., & Hägglund, M. (2016). Hamstring injuries have increased by 4% annually in men's professional football, since 2001: A 13-year longitudinal analysis of the UEFA elite club injury study. *British Journal of Sports Medicine, 50*, 731–737. https://doi.org/10.1136/bjsports-2015-095359.

Finch, C. (2006). A new framework for research leading to sports injury prevention. *Journal of Science and Medicine in Sport, 9*, 3–9. https://doi.org/10.1016/j.jsams.2006.02.009.

Fuller, C. W. (2018). *Injury risk (burden), risk matrices and risk contours in team sports: A review of principles, practices and problems. Sport Med* Published Online First. https://doi.org/10.1007/s40279-018-0913-5.

Fuller, C. W., Brooks, J. H. M., Cancea, R. J., et al. (2007). Contact events in rugby union and their propensity to cause injury. *British Journal of Sports Medicine, 41*, 862–867. https://doi.org/10.1136/bjsm.2007.037499.

Fuller, C. W., Laborde, F., Leather, R. J., et al. (2008). International rugby board rugby world cup 2007 injury surveillance study. *British Journal of Sports Medicine, 42*, 452–459. https://doi.org/10.1136/bjsm.2008.047035.

Fuller, C. W., Molloy, M. G., Bagate, C., et al. (2007). Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Clinical Journal of Sport Medicine, 17*, 177–181. https://doi.org/10.1097/JSM.0b013e31803220b3.

Fuller, C. W., Sheerin, K., & Targett, S. (2013). Rugby world cup 2011: International rugby board injury surveillance study. *British Journal of Sports Medicine, 47*, 1184–1191. https://doi.org/10.1136/bjsports-2012-091155.

Holtzhausen, L. J., Schwellnus, M. P., Jakoet, I., et al. (2006). The incidence and nature of injuries in South African rugby players in the rugby Super 12 competition. *South African Medical Journal, 96*, 1260–1265 (doi:NOT FOUND).

John, C. (2013). *Pezzullo. Biostatistics for dummies. Canada*. John Wiley & Sons, Inc.. https://books.google.co.uk/books?id=tagRAAAAQBAJ&pg=PA206&dq=confidence+interval+incidence&hl=en&sa=X&ved=0ahUKEwiR6bmR2J7ZAhWGC-wKHS1sD8kQ6wEIUDAG#v=onepage&q=confidence interval incidence&f=false

Junge, A., & Dvorak, J. (2013). Injury surveillance in the world football tournaments 1998-2012. *British Journal of Sports Medicine, 47*, 782–788. https://doi.org/10.1136/bjsports-2013-092205.

Mathema, P., Evans, D., Moore, I. S., et al. (2016). Concussed or not? An assessment of concussion experience and knowledge within elite and semiprofessional rugby union. *Clinical Journal of Sport Medicine, 26*, 320–325. https://doi.org/10.1097/JSM.0000000000000256.

Moore, I. S., Ranson, C., & Mathema, P. (2015). Injury risk in international rugby union: Three-year injury surveillance of the Welsh national team. *Orthopaedic Journal of Sports Medicine, 3*, 1–9. https://doi.org/10.1177/2325967115596194.

Owen, S. M., Venter, R. E., Du, T. S., et al. (2015). Acceleratory match-play demands of a super rugby team over a competitive season. *Journal of Sports Sciences, 33*, 2061–2069. https://doi.org/10.1080/02640414.2015.1028086.

Pulling, C., & Stenning, M. (2015). Offloads in rugby union: Northern and southern hemisphere international teams. *International Journal of Performance Analysis in Sport, 15*, 217–228. https://doi.org/10.1080/24748668.2015.11868788.

R Core Team. R. (2013). *A language and environment for statistical computing*.

Rae, K., & Orchard, J. (2007). The Orchard Sports Injury Classification System (OSICS) version 10. *Clinical Journal of Sport Medicine, 17*, 201–204. https://doi.org/10.1097/JSM.0b013e318059b536.

Rafferty, J., Ranson, C., Oatley, G., et al. (2018). On average, a professional rugby union player is more likely than not to sustain a concussion after 25 matches. *British Journal of Sports Medicine, 44*, 1–13. https://doi.org/10.1136/bjsports-2017-098417.

Ranson C, George J, Rafferty J, et al. Playing surface and UK professional rugby union injury risk. Journal of Sports Sciences

Ranson, C., Hurley, R., Rugless, L., et al. (2013). International cricket injury surveillance: A report of five teams competing in the ICC cricket world cup 2011. *British Journal of Sports Medicine, 47*, 637–643. https://doi.org/10.1136/bjsports-2012-091783.

Roberts, S. P., Trewartha, G., Higgitt, R. J., et al. (2008). The physical demands of elite English rugby union. *Journal of Sports Sciences, 26*, 825–833. https://doi.org/10.1080/02640410801942122.

Rugby Football Union (England). (2016). The professional rugby injury surveillance project. *Injury Prevention, 22*, 188. http://ezproxy.lib.ucalgary.ca/login?url=http://search.ebscohost.com/login.aspx?direct=true%7B&%7Ddb=s3h%7B&%7DAN=115758448%7B&%7Dsite=ehost-live.

Toohey, L. A., Drew, M. K., Fortington, L. V., et al. (2018). An updated subsequent injury categorisation model (SIC-2.0): Data-driven categorisation of subsequent injuries in sport. *Sports Medicine, 48*, 2199–2210. https://doi.org/10.1007/s40279-018-0879-3.

Tucker, R., Raftery, M., Kemp, S., et al. (2017). Risk factors for head injury events in professional rugby union: A video analysis of 464 head injury events to inform proposed injury prevention strategies. *British Journal of Sports Medicine, 51*, 1152–1157. https://doi.org/10.1136/bjsports-2017-097895.

Walden, M., Hagglund, M., & Ekstrand, J. (2005). *Injuries in Swedish elite football - a prospective study on injury definitions, risk for injury and injury pattern during 2001.pdf* (pp. 118–125).

Williams, S., Trewartha, G., Kemp, S., et al. (2013). A meta-analysis of injuries in senior men's professional Rugby Union. *Sports Medicine, 43*, 1043–1055. https://doi.org/10.1007/s40279-013-0078-1.

Williams, S., Trewartha, G., Kemp, S. P. T., et al. (2017). How much rugby is too much? A seven-season prospective cohort study of match exposure and injury risk in professional rugby union players. *Sports Medicine, 47*, 2395–2402. https://doi.org/10.1007/s40279-017-0721-3.

World Rugby. Head injury assessment (HIA) protocol. https://playerwelfare.worldrugby.org/concussion. (Accessed 15 May 2019). Vols. 1–2.